Demand Management and Process Optimization for WWTPs

Brendan Held, EPA Region 4

KY EEC Demand Management Conference

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Overview

- Wastewater basics and the activated sludge process
- Energy use at WWTPs
- Demand Management Strategies at WWTPs
- Demand Management Strategies at WTPs
- Case Studies
- Resources

Activated Sludge Process

It's a bacteria farm!

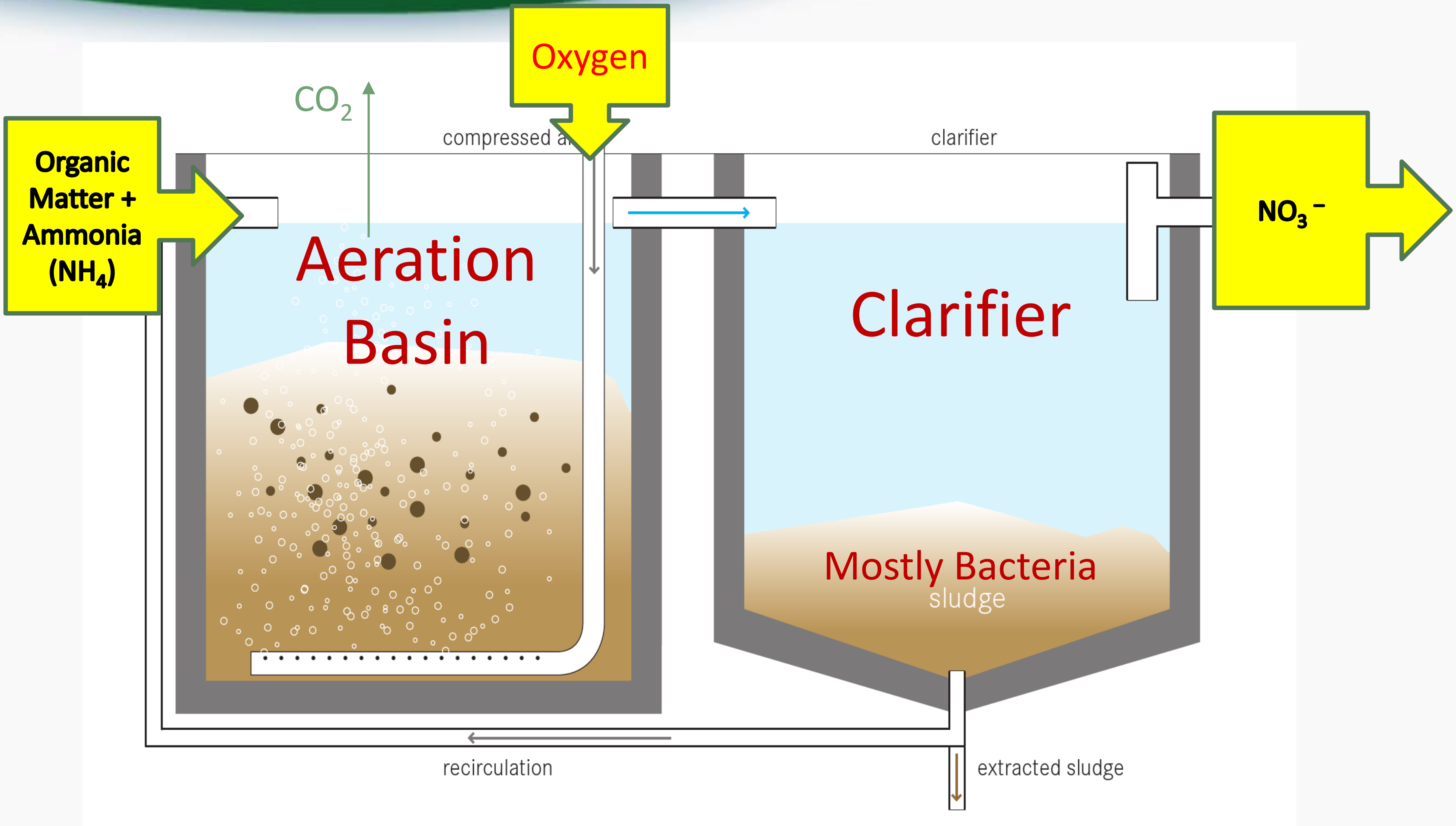
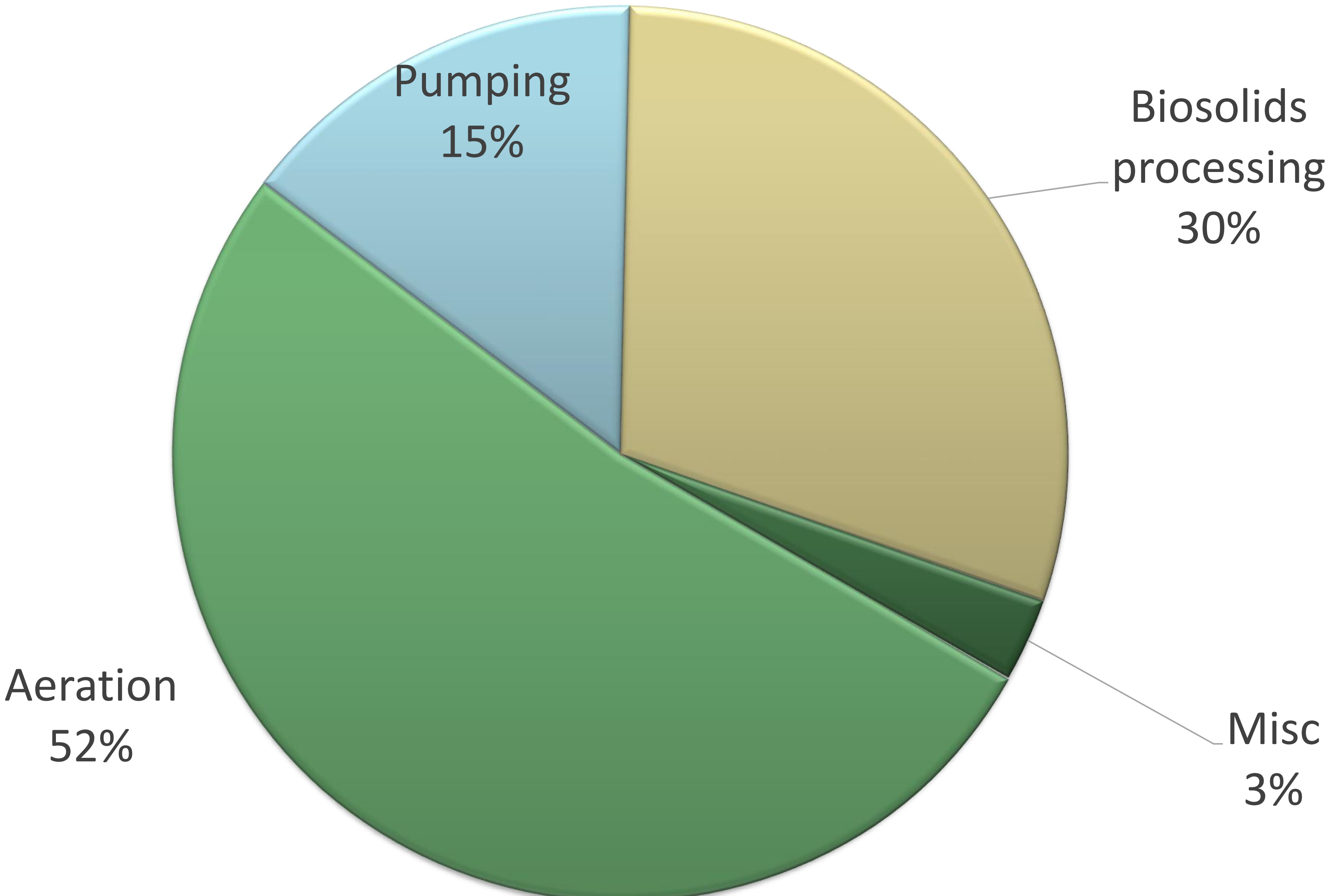
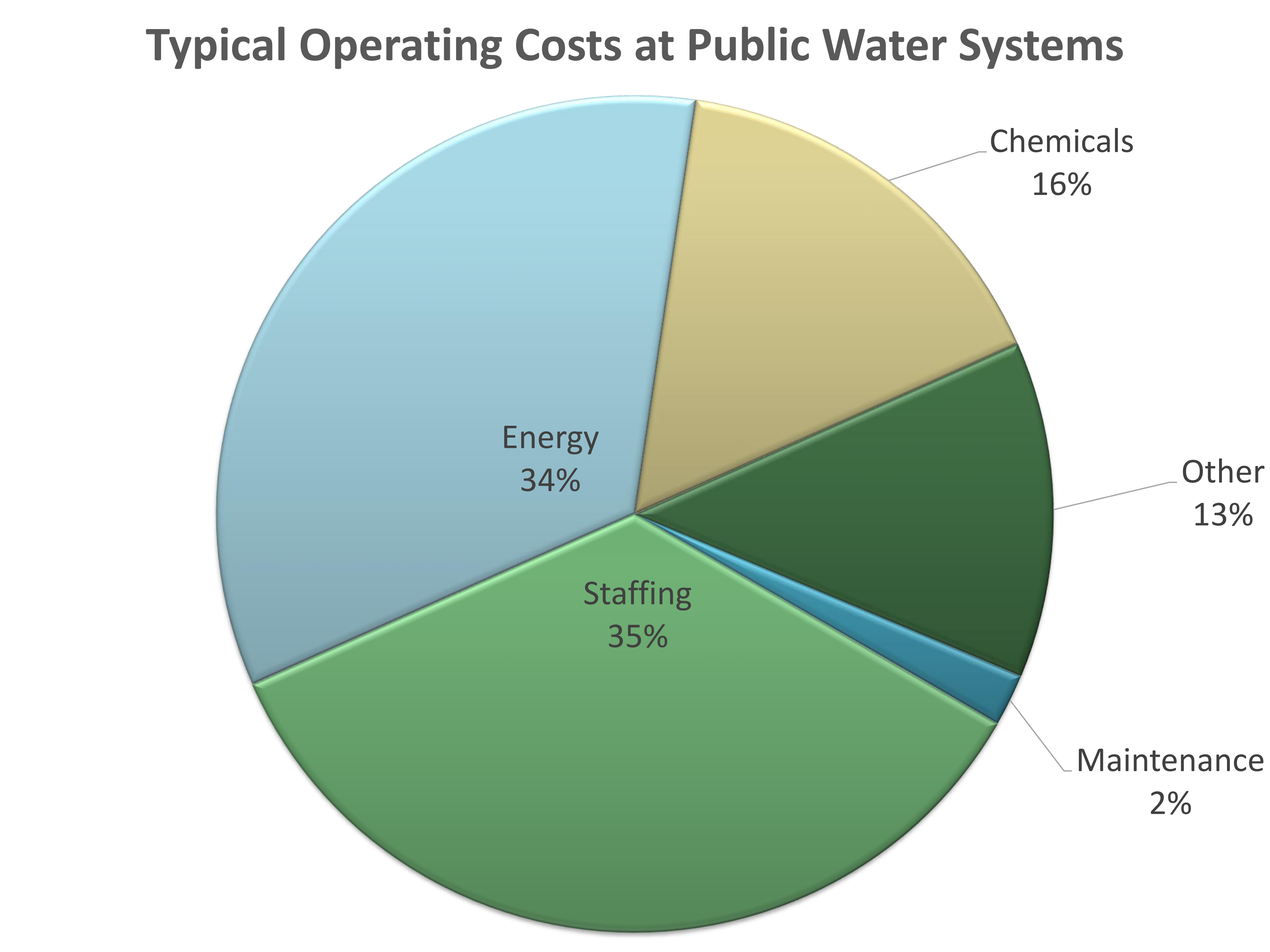


Image source: www.eawag.ch

Typical Energy Use at WWTPs



Source: Hazen and Sawyer


Typical Operating Costs at Public Water Systems
Chemicals
16%
Energy
34%
Other
13%
Staffing
35%
Maintenance
2%

Recognizing the Opportunity

Excess by design:

- 20 year design life means excess capacity for most of a plant's service.
- Some growth forecasts are based on the premise that excess capacity will lure industry.
- Operations manuals recommend a conservative 2.0 mg/L dissolved oxygen concentration at all times.

Excess by habit:

- If equipment is available, it tends to get used. (See first point.)
- If 2.0 mg/L of dissolved oxygen is good, 3.0 must be better. (It isn't.)
- Who sees the savings? Operators <u>rarely</u> see bills. (And worry about budget cuts if savings are too effective.)

Demand Management Strategies at WWTPs

Strategies for Reducing Aeration

- Reduce aerator runtimes, and/or number of aerators in service
- VFDs and improved SCADA can help ensure a proper DO setpoint
- BioTiger, an Excel-based model developed through cooperation of DOE, EPA and University of Memphis (More on this under Resources.)

Intermittent Aeration

It's a bacteria farm!

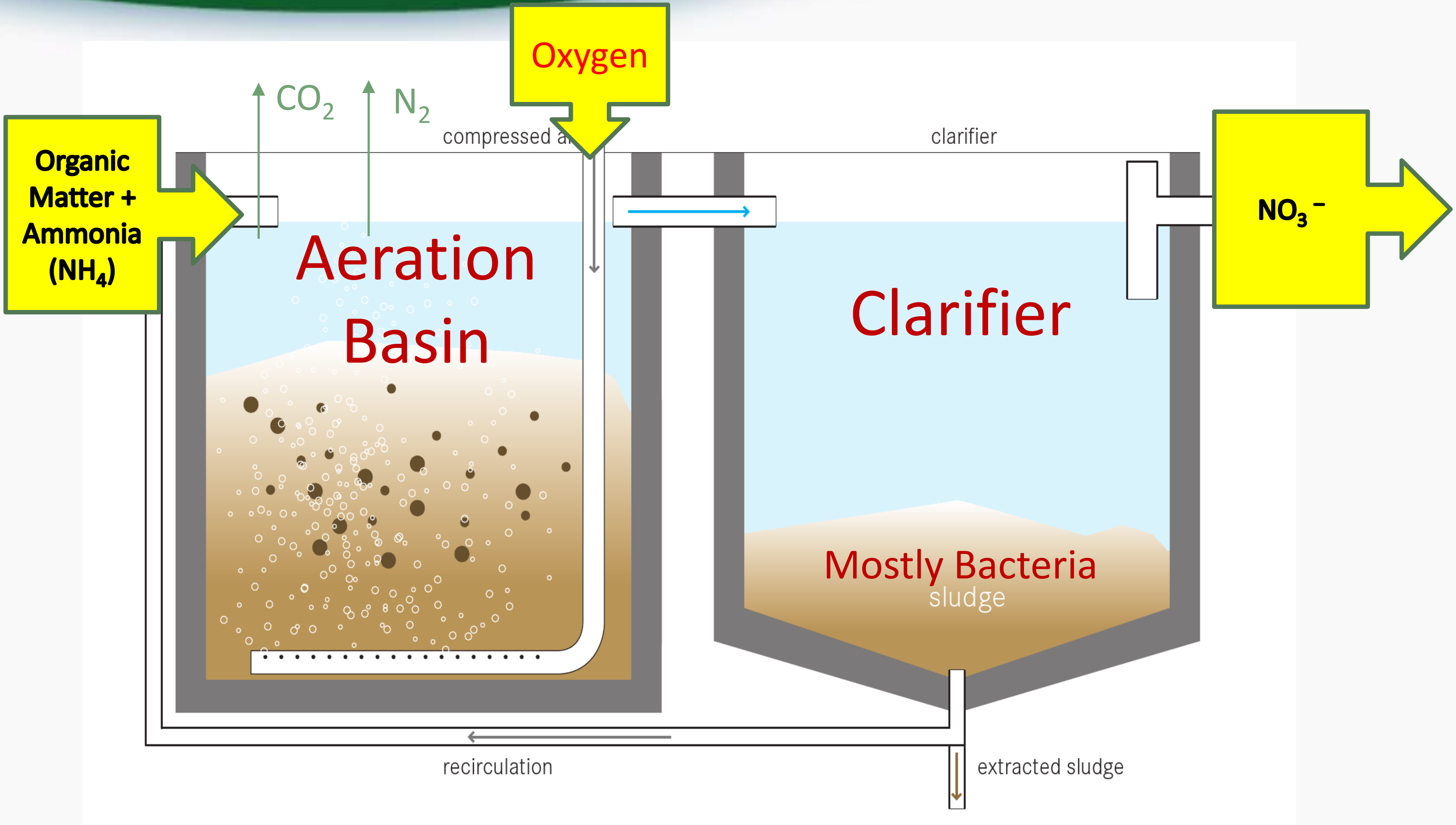


Image source: www.eawag.ch

Intermittent aeration

- Nitrogen enters the WWTP as ammonia and organic nitrogen, such as urea
- Slow growing AOBs use supplied oxygen to convert those forms to nitrite (NO2) and nitrate (NO3)
  - This also consumes alkalinity. This is ok to a degree, but if alkalinity runs out, the system could become acidic and impair performance
  - Many facilities do this to meet strict ammonia limit
- Given the right conditions, other bacteria can use nitrite and nitrate in their metabolic process
  - These conditions include a low oxygen environment, which can be created when aeration is reduced or paused
  - This returns alkalinity to the system and can improve solids settling
  - Many systems do not routinely perform this step unless a limit of Total Nitrogen is imposed

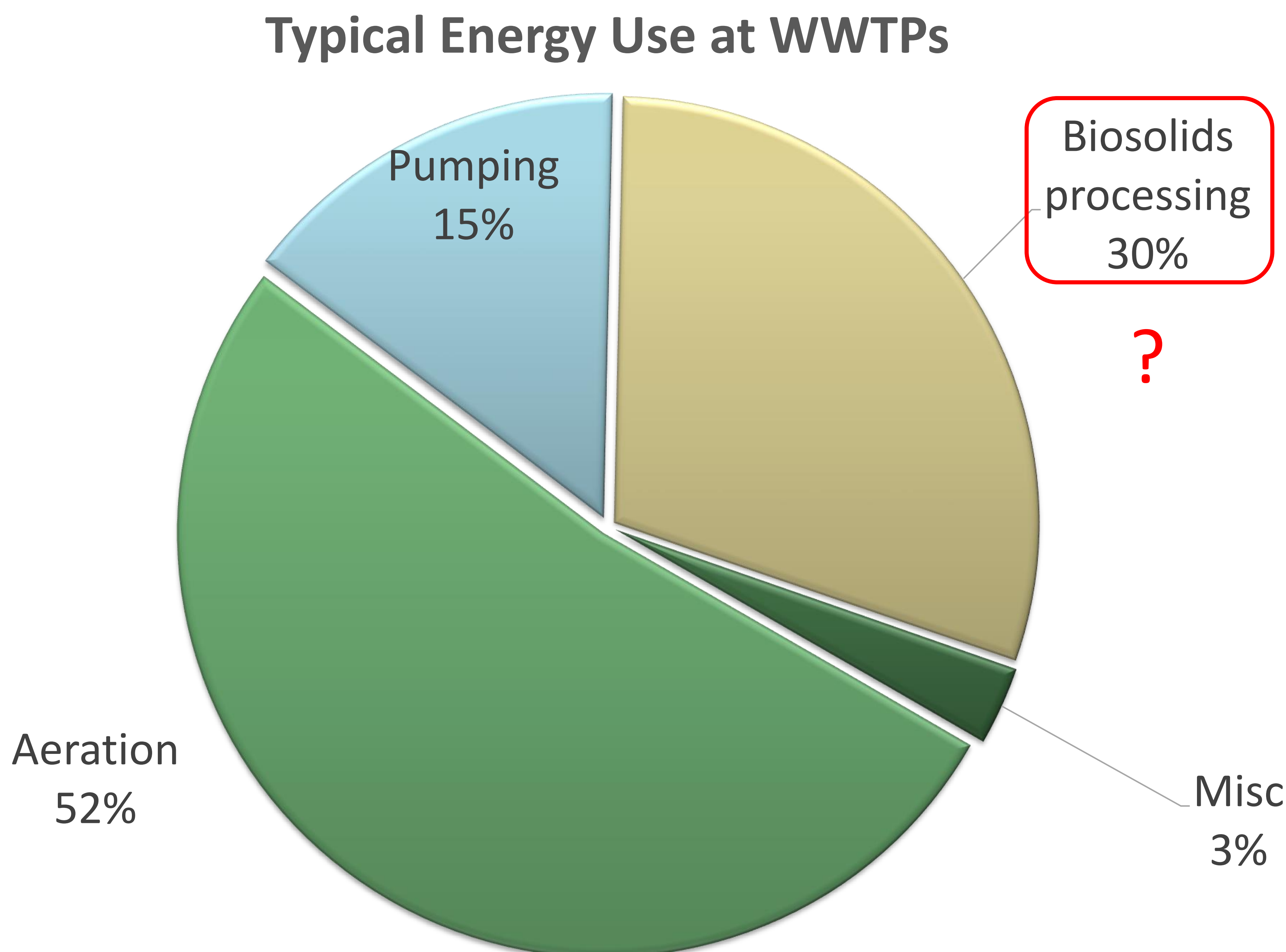
A word about inrush current

Myth: Frequent starts and stops of large motors will increase my demand

Fact: There is a large spike in kW draw when motors are started (up to 6x “full” power) but the spike only lasts a couple seconds. Over the 15-minute demand window, this amounts to less than 0.2% increase.

Another Fact: This excess current will dissipate in the form of heat, which can accelerate wear. This is where soft starts can help.

Strategies for reducing aeration



Activated Sludge Process

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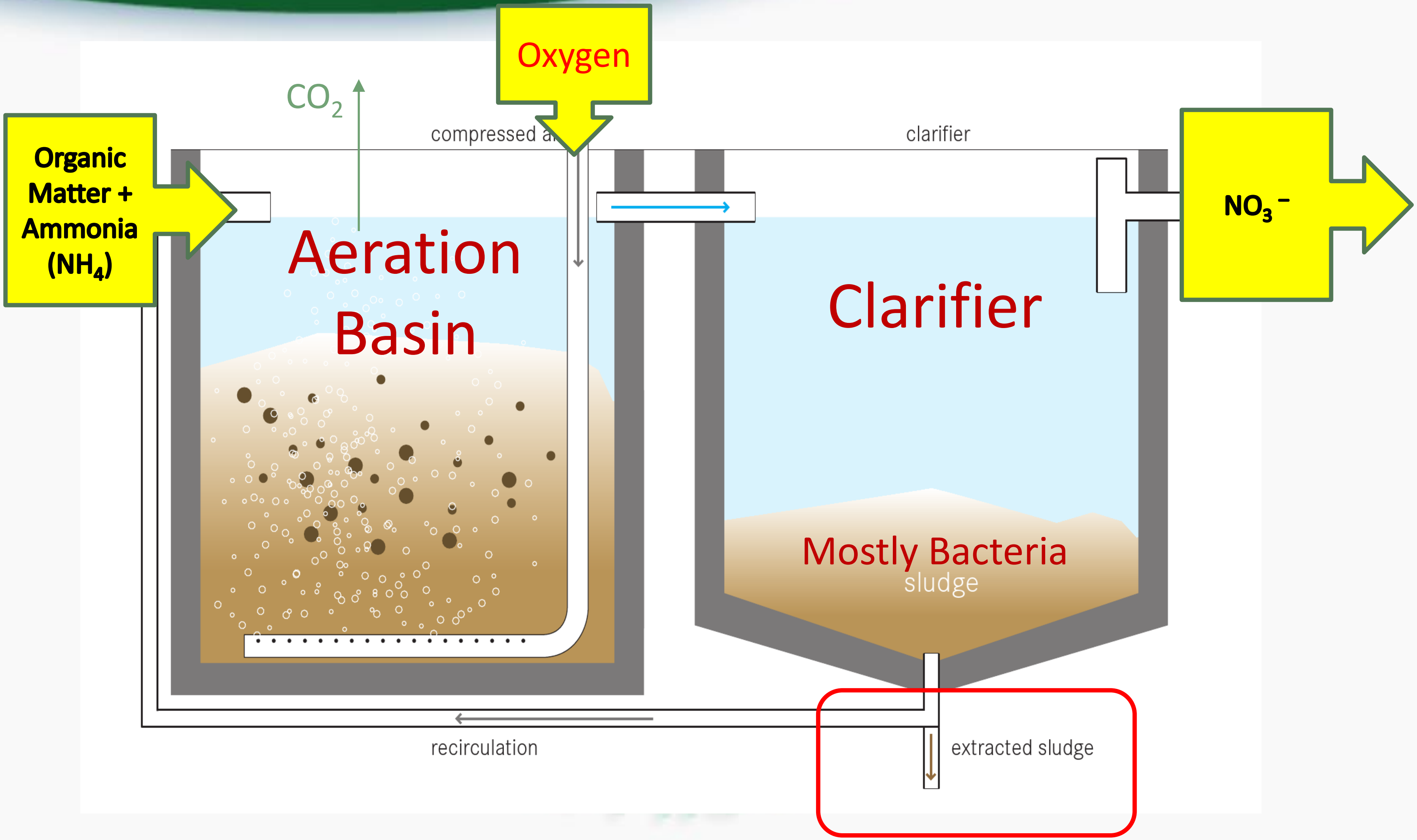

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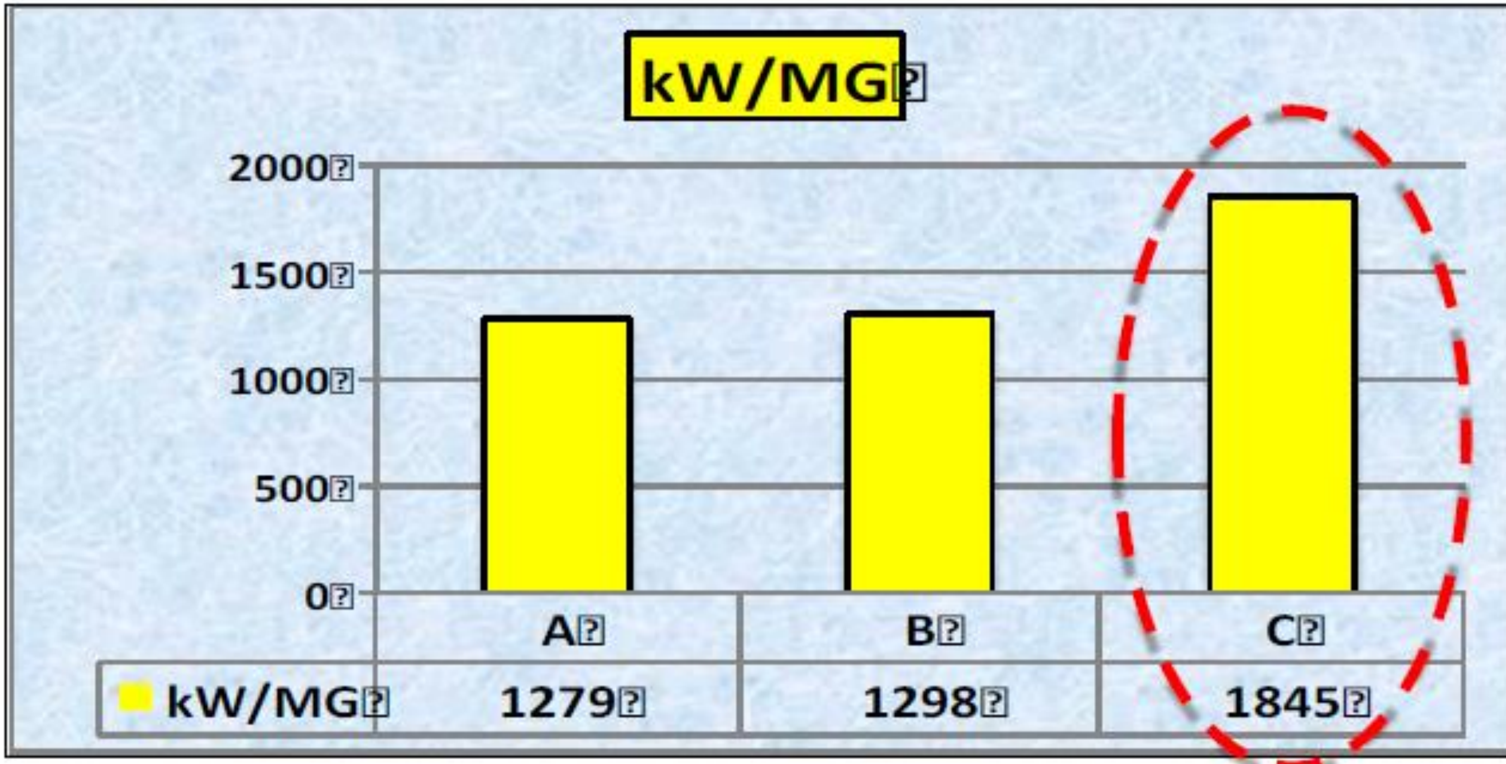
Aerobic Digestion

- Waste sludge or biosolids are further processed to reduce the risk of spreading pathogens when they are ultimately disposed.
- Most often this is a process called digestion. Solids are collected and aerated to allow for further destruction of the solids.
- In facilities with excess capacity, biosolids often remain in the activated sludge system much longer than designed.
- Solids are often well digested before they are removed, requiring less aeration and detention time in the digester.
- Using a Specific Oxygen Uptake Rate (SOUR) test to meet vector attraction reduction requirements is preferred to measuring destruction of solids.

Demand Management at Drinking Water Plants

Real-world Well Analysis Findings



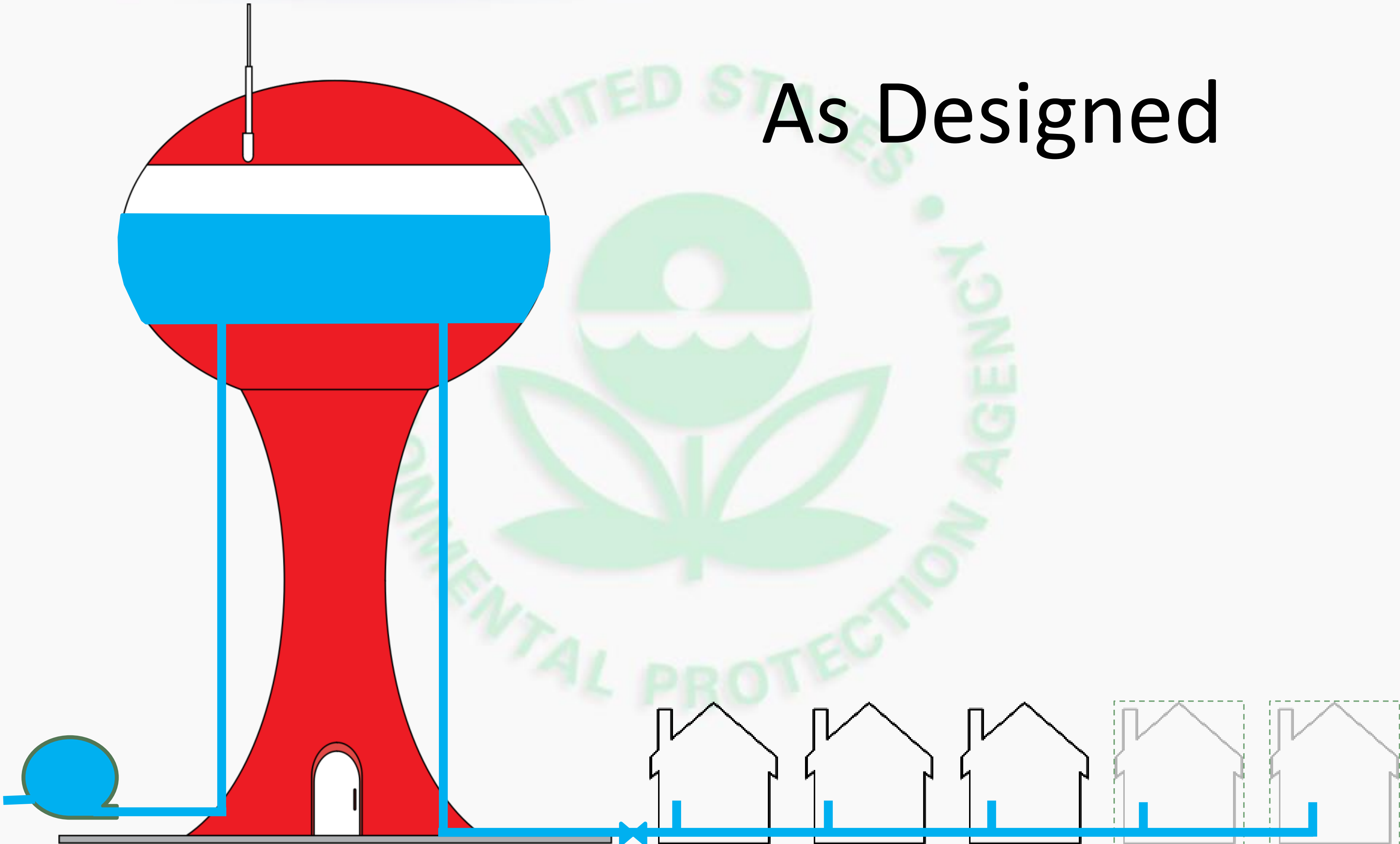
Well C uses 40% more power to do the same amount of work. Just moving some of this load over to another well can save thousands of dollars a year. Actions such as these gain credibility and make it easier to get money for future projects. No tools were required, just looking at the data.

SCRWA

Source: Lonnie Russell (SCRWA and EnergyMan, LLC)

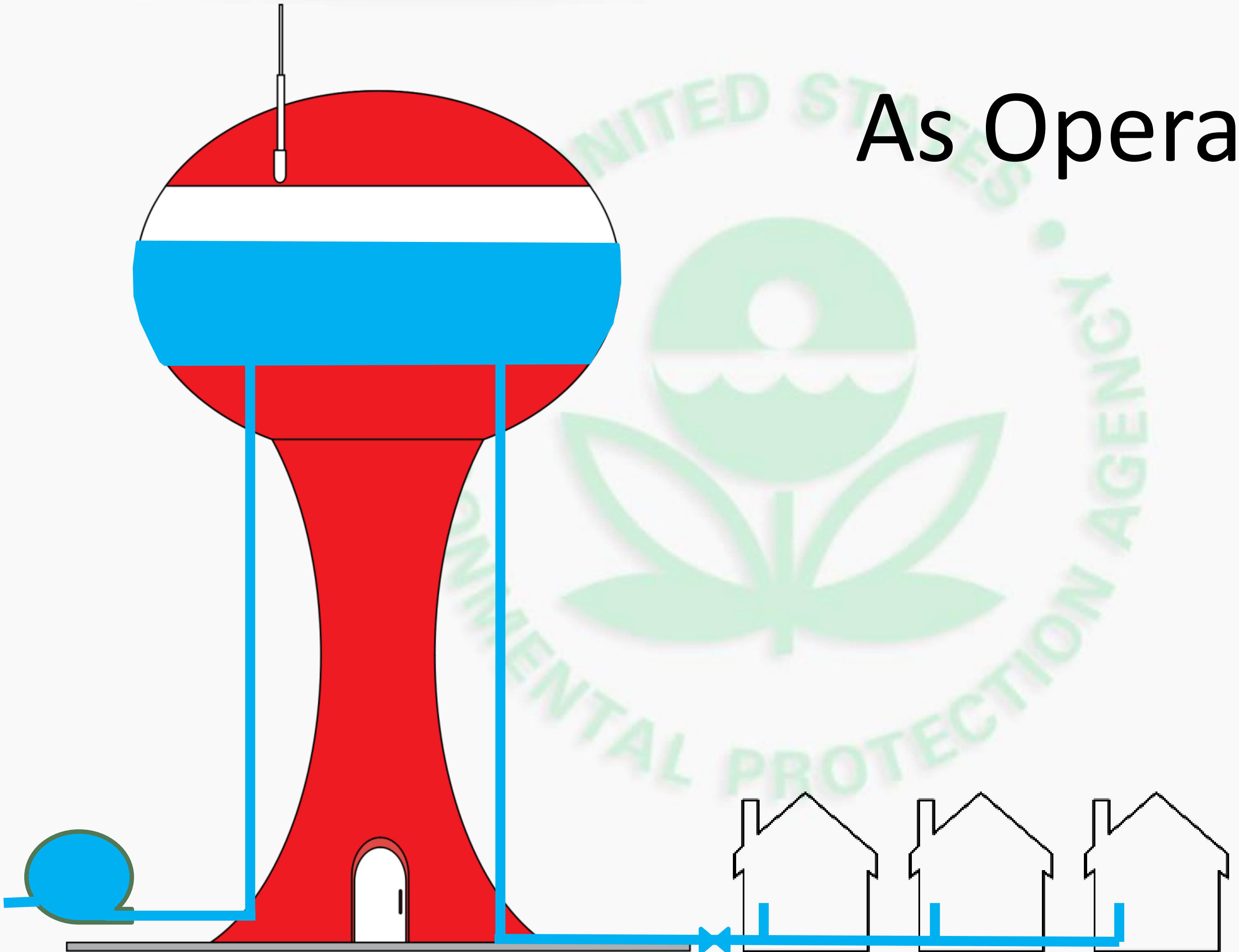
Elevated Tanks – Top Capacity Level

As Designed



Elevated Tanks – Top Capacity Level

As Operated



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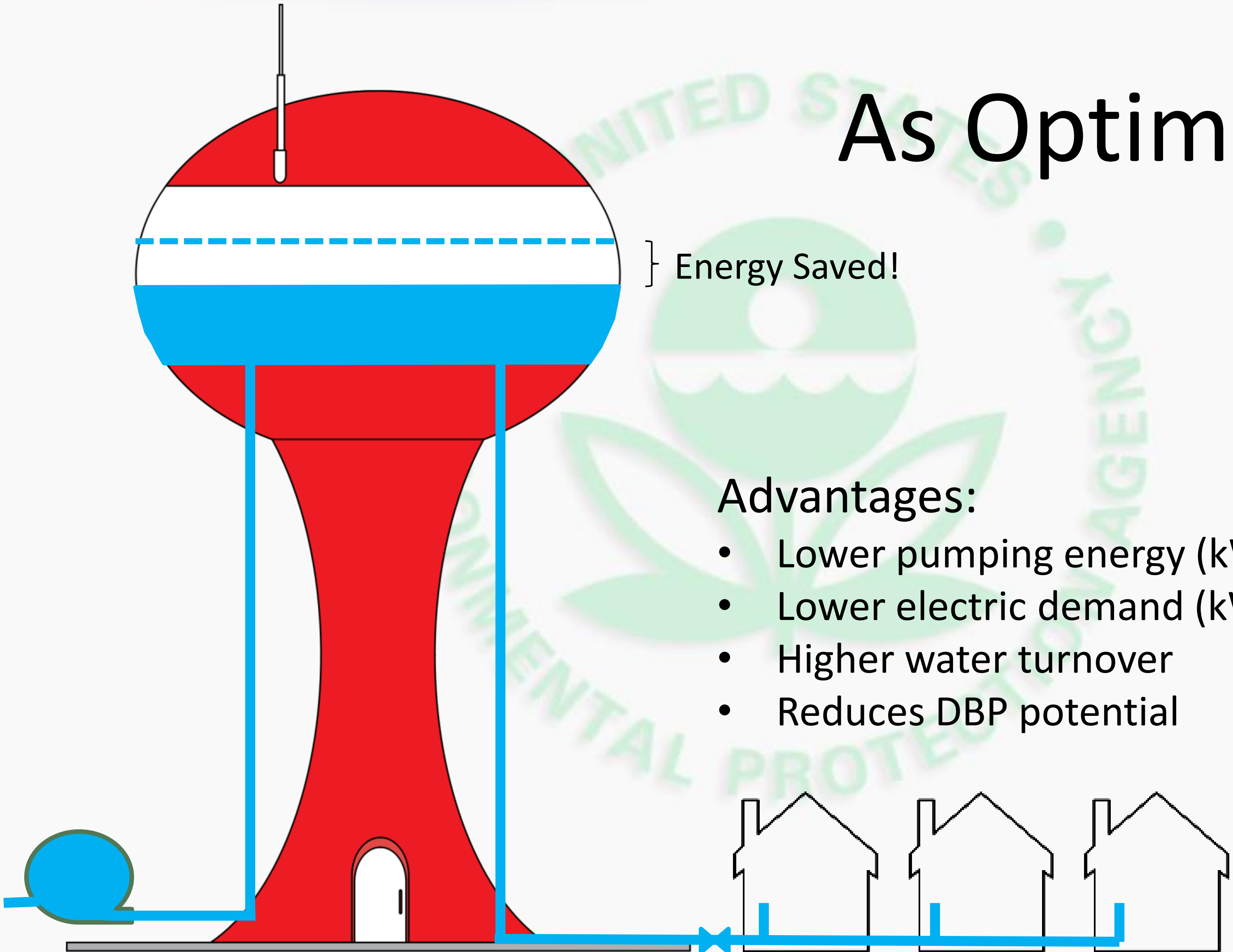


As Optimized

Advantages:

- Lower pumping energy (kWh)
- Lower electric demand (kW)
- Higher water turnover
- Reduces DBP potential

How are you being charged?

Time of Use Rates?
Real Time Pricing?

$ per kWh per kVA??
Contract Minimums?

Incentive Programs?

Early Energy Team Objectives

How are you being charged?

Demand Charge Line Item

Ratchet effect

Higher kW demand = higher kWh marginal price

MONTHLY RATE (SECONDARY)

Base Charge:
$50.00 per customer; plus

Charge for Billing Capacity:
$4.74 per kW of billing capacity; plus

Charge for Energy:
For the first 250 kWh per kW of billing capacity:
8.9331¢ per kWh for all kWh.

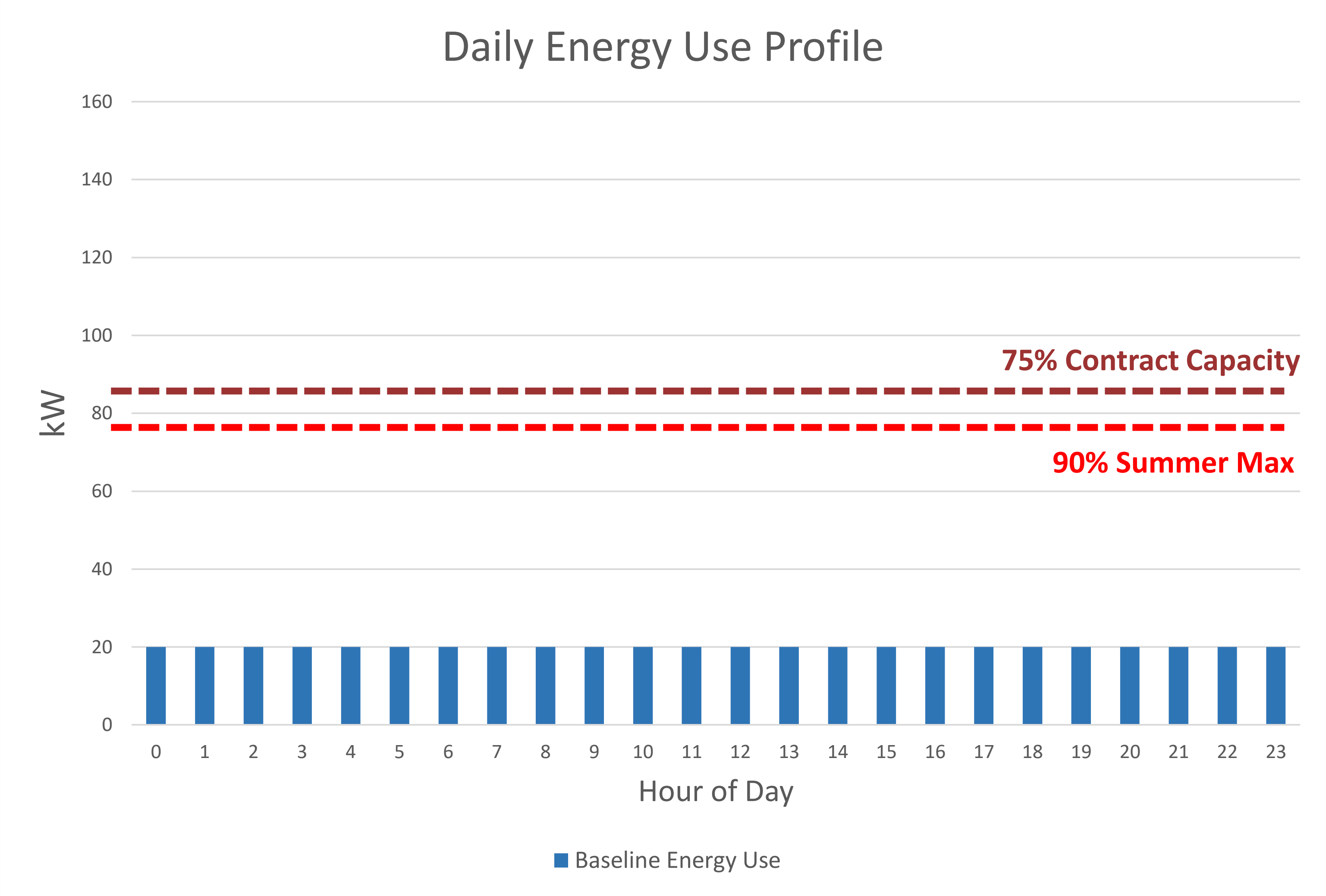
For all over 250 kWh per kW of billing capacity:
6.9668¢ per kWh for all kWh.

DETERMINATION OF BILLING CAPACITY

The monthly billing capacity shall be the measured maximum integrated fifteen (15) minute capacity during each billing period of approximately thirty (30) days measured in kW; provided, however, that such capacity shall be no less than ninety percent (90%) of the measured maximum capacity requirements established during the billing months of June through September falling within the eleven (11) months preceding the billing period or seventy-five percent (75%) of the contracted capacity, whichever is greater. No billing capacity shall be for less than 5 kW for secondary service from the distribution facilities, 25 kW for primary service, or 100 kW for service from the transmission facilities.

Source: Alabama Power LPM Rate Schedule

How are you being billed?



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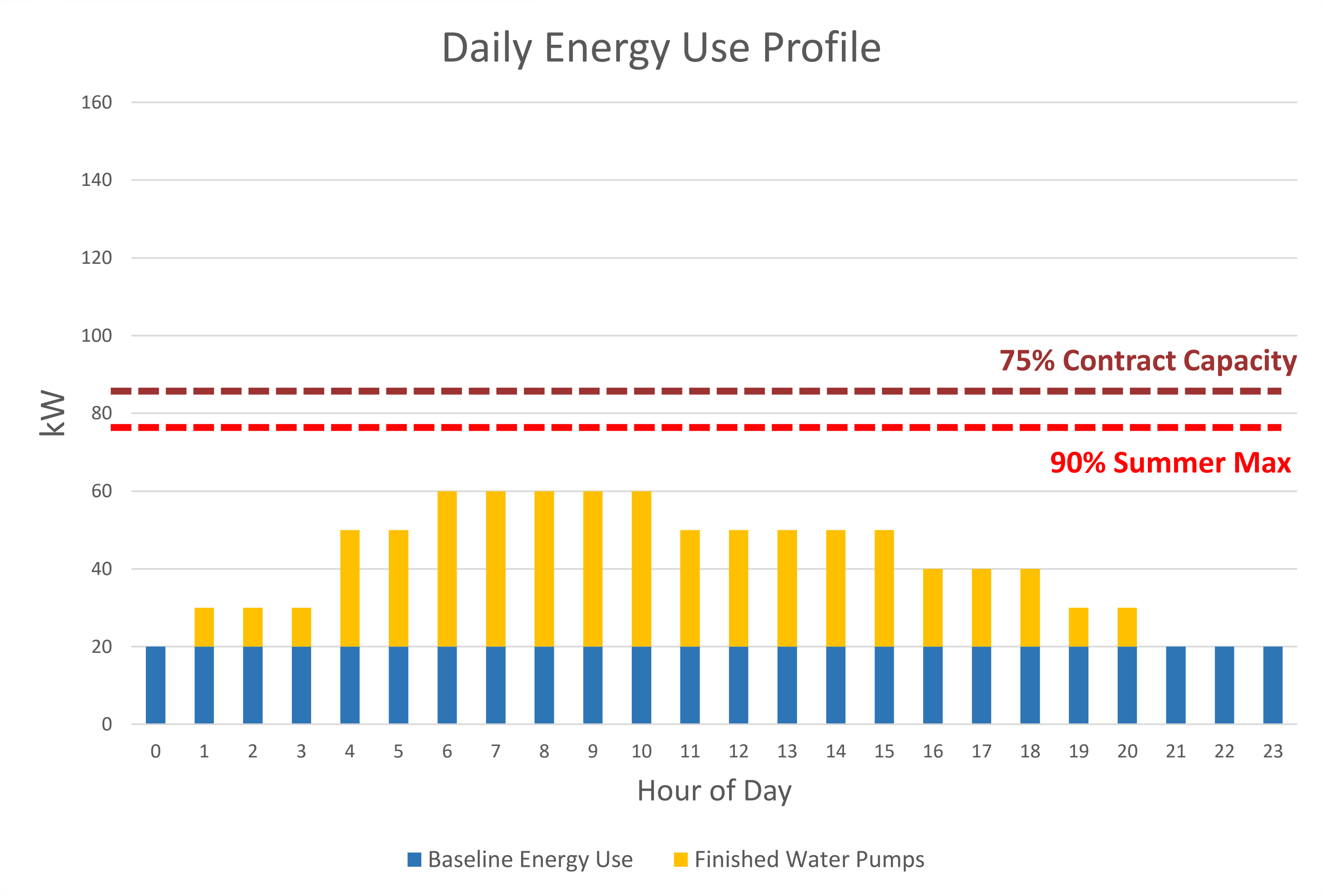

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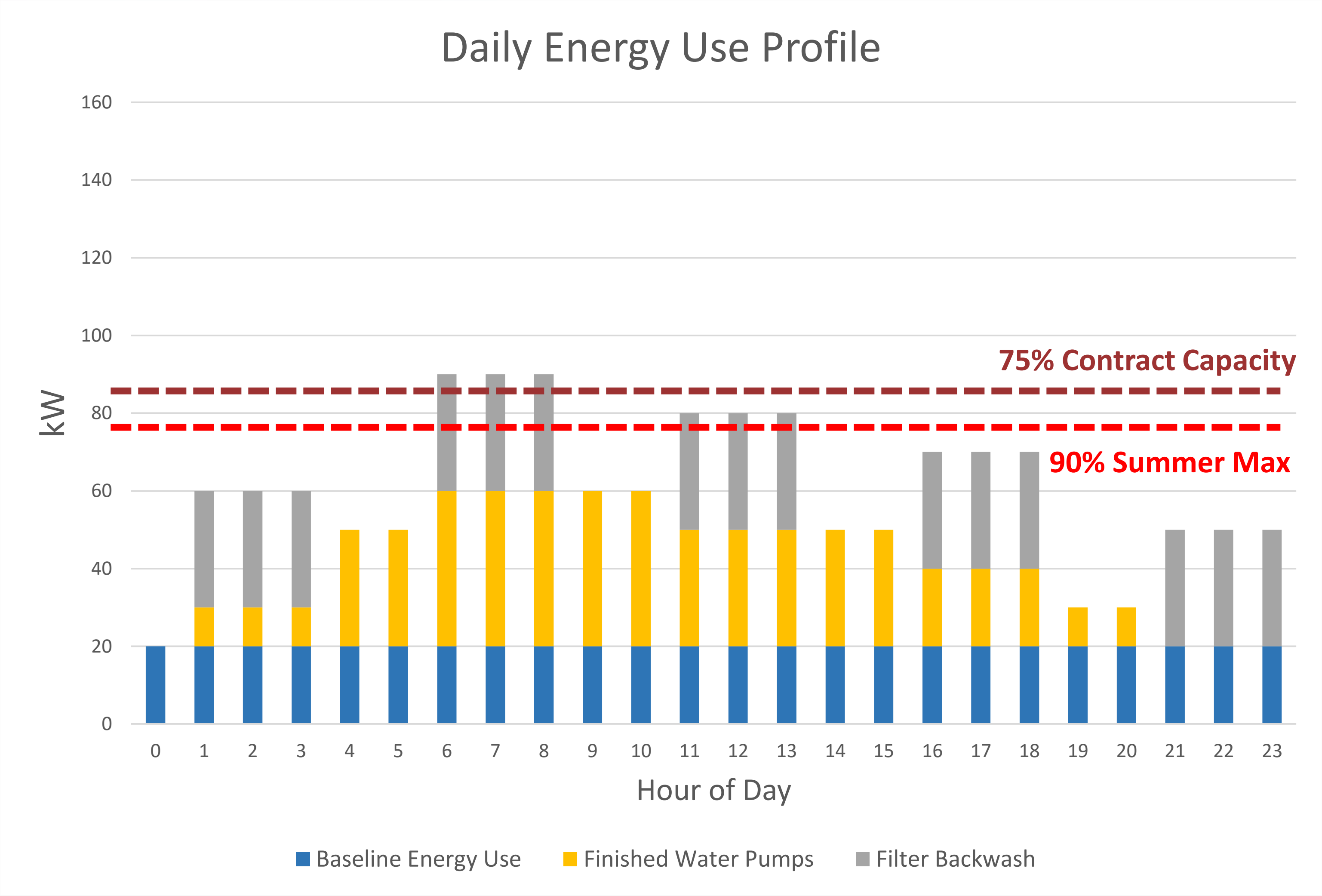

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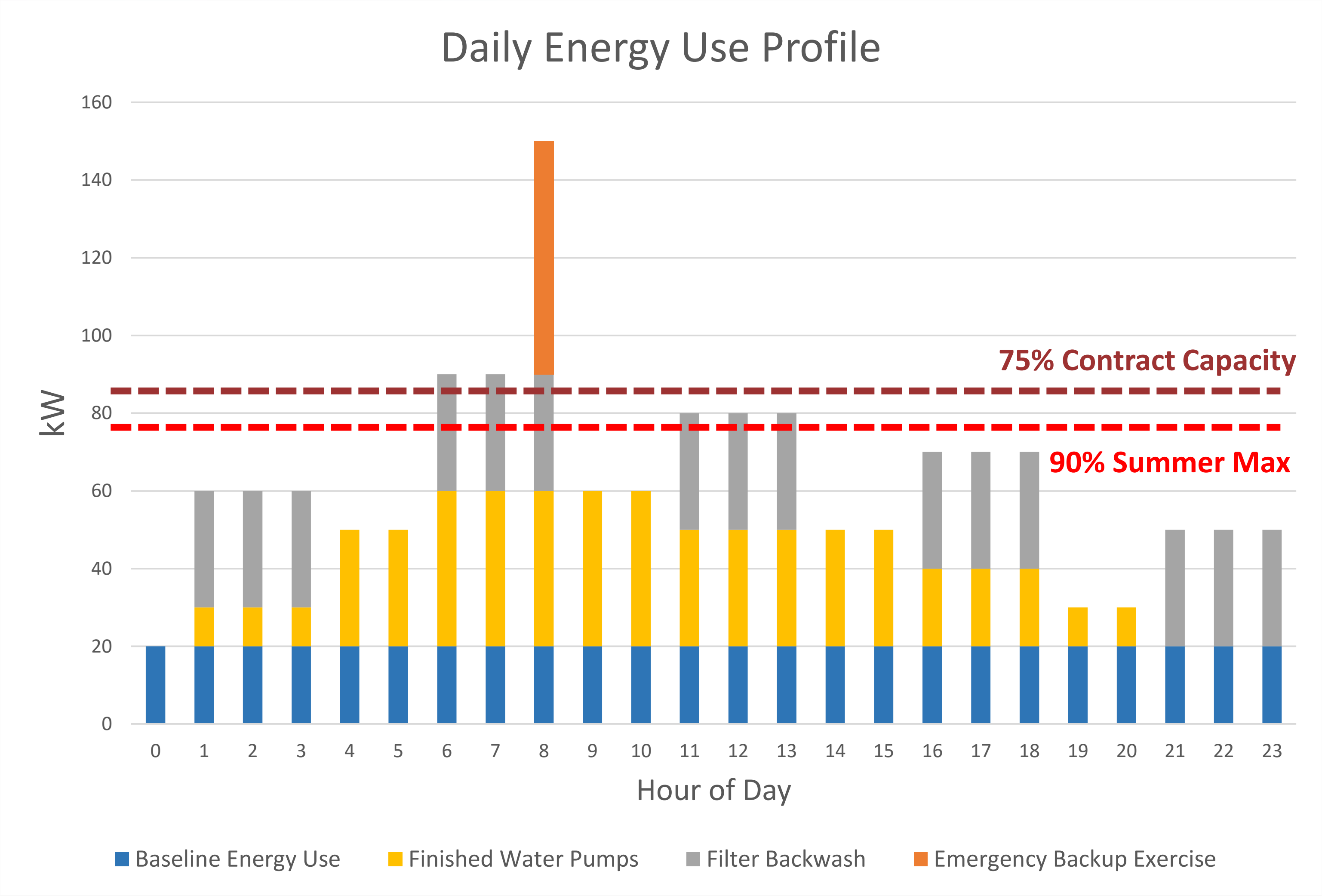

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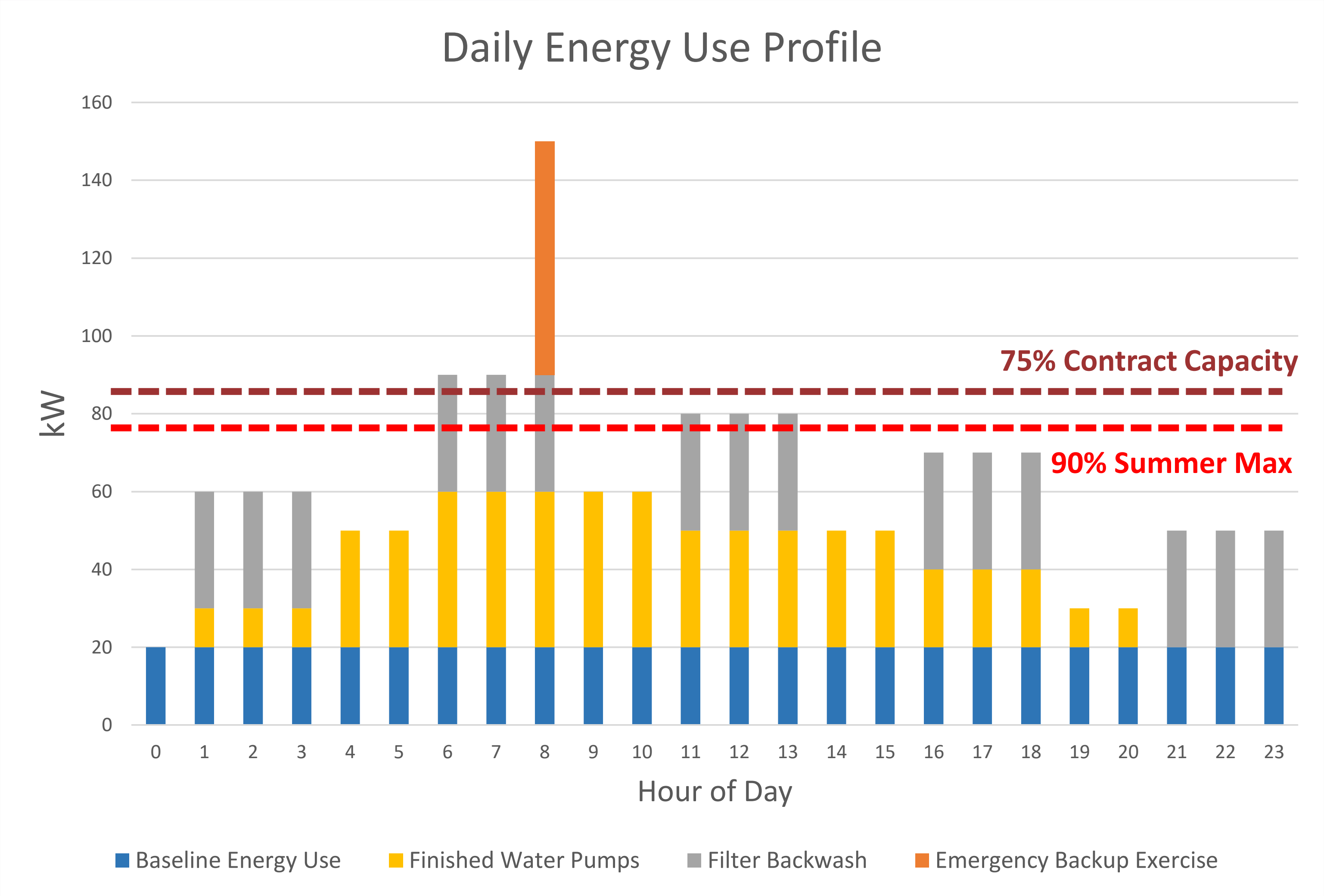
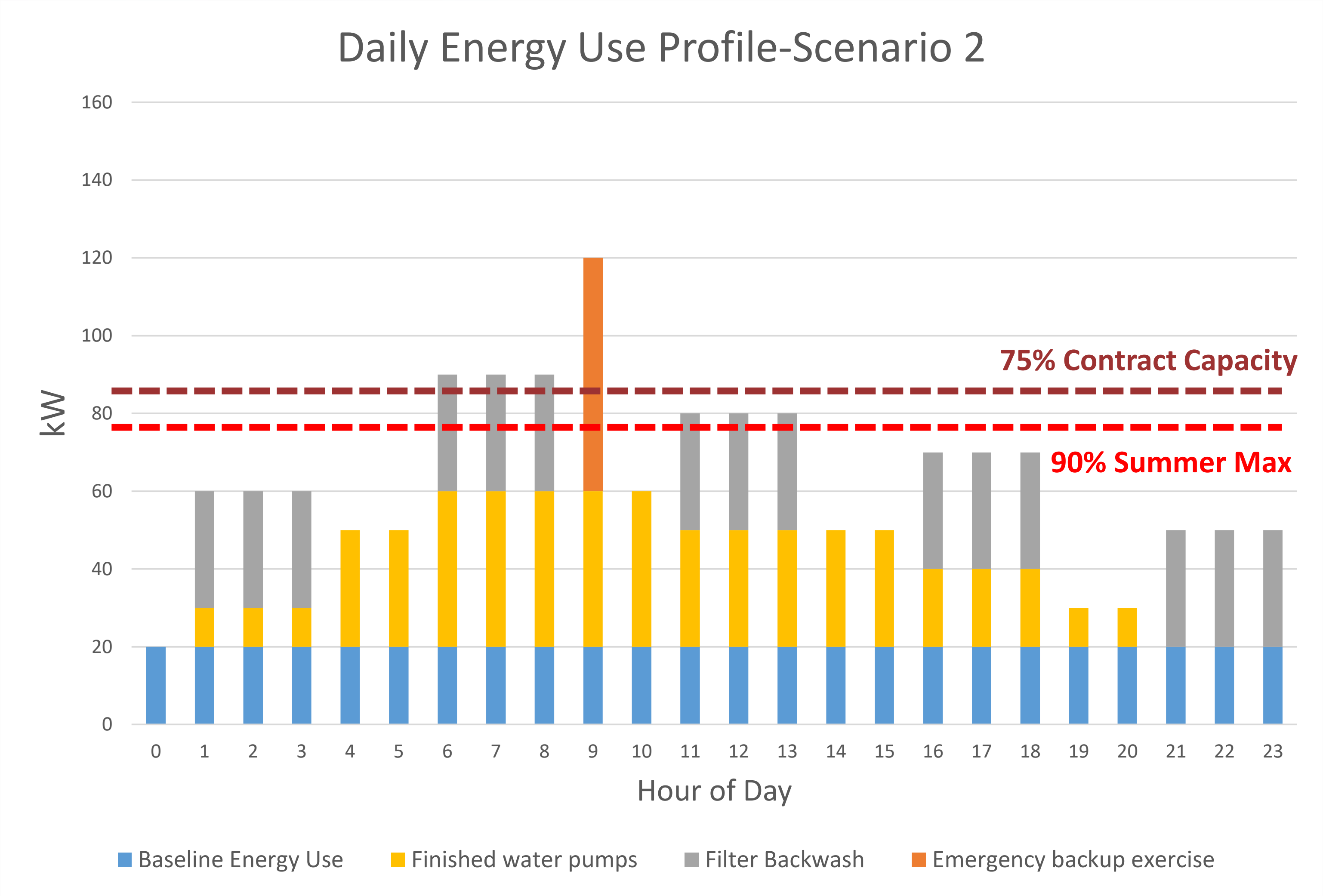
Demand Management



Demand Management

	Scenario 1
kW billing capacity	150
kWh consumed	45300
kWh/kW	302
Total kW cost	$711
kWh cost (up to 250 kWh/kW)	$3350
kWh cost (over 250 kWh/kW)	$2613
Base charge	$50
Total Daily Charge	**$6723**
% Savings	-
Annual Savings	-

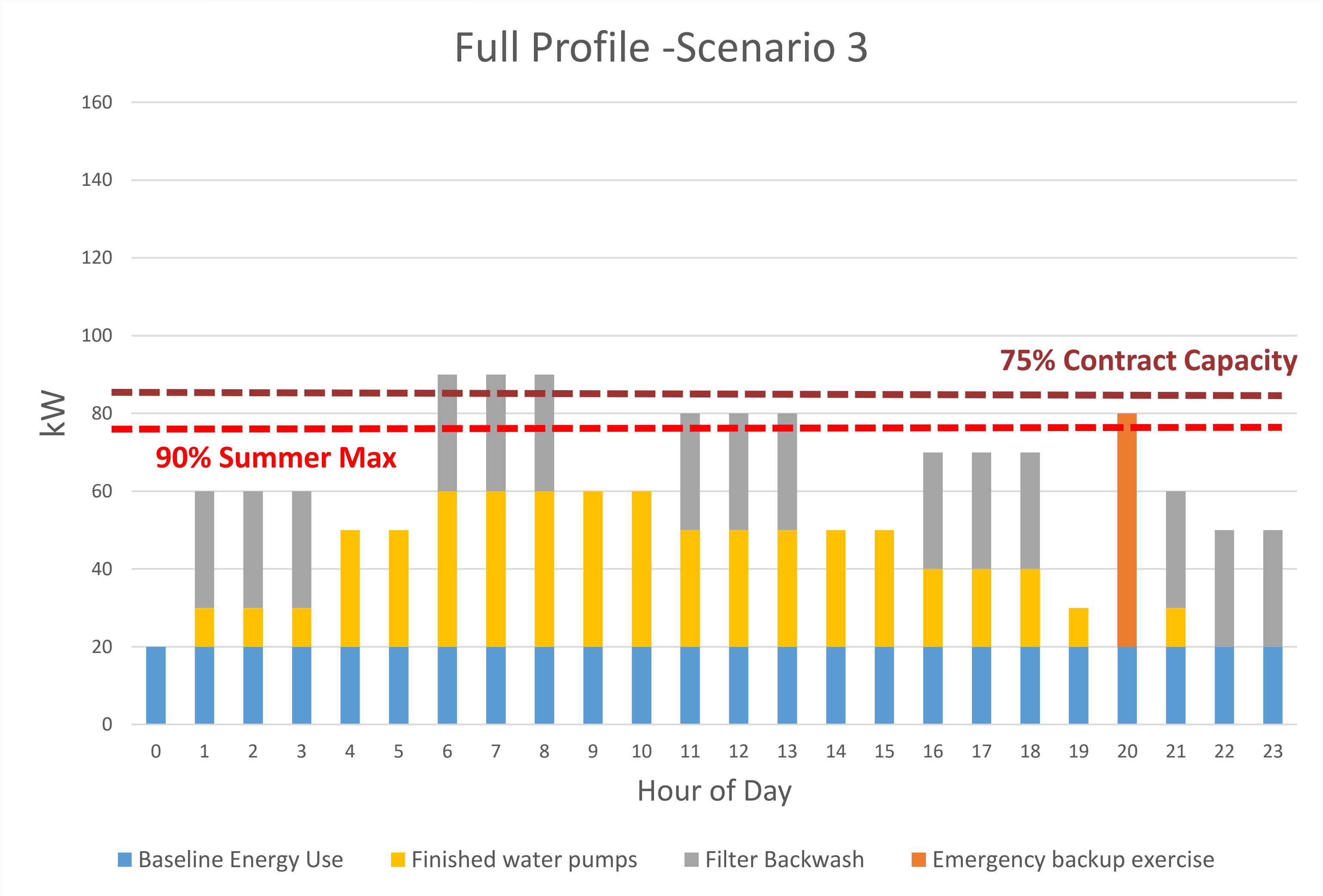
Demand Management



Demand Management

	Scenario 1	Scenario 2
kW billing capacity	150	120
kWh consumed	45300	45300
kWh/kW	302	378
Total kW cost	$711	$569
kWh cost (up to 250 kWh/kW)	$3350	$2680
kWh cost (over 250 kWh/kW)	$2613	$2090
Base charge	$50	$50
Total Charge	**$6723**	**$5389**
% Savings	-	*19.9%*

Demand Management



Demand Management

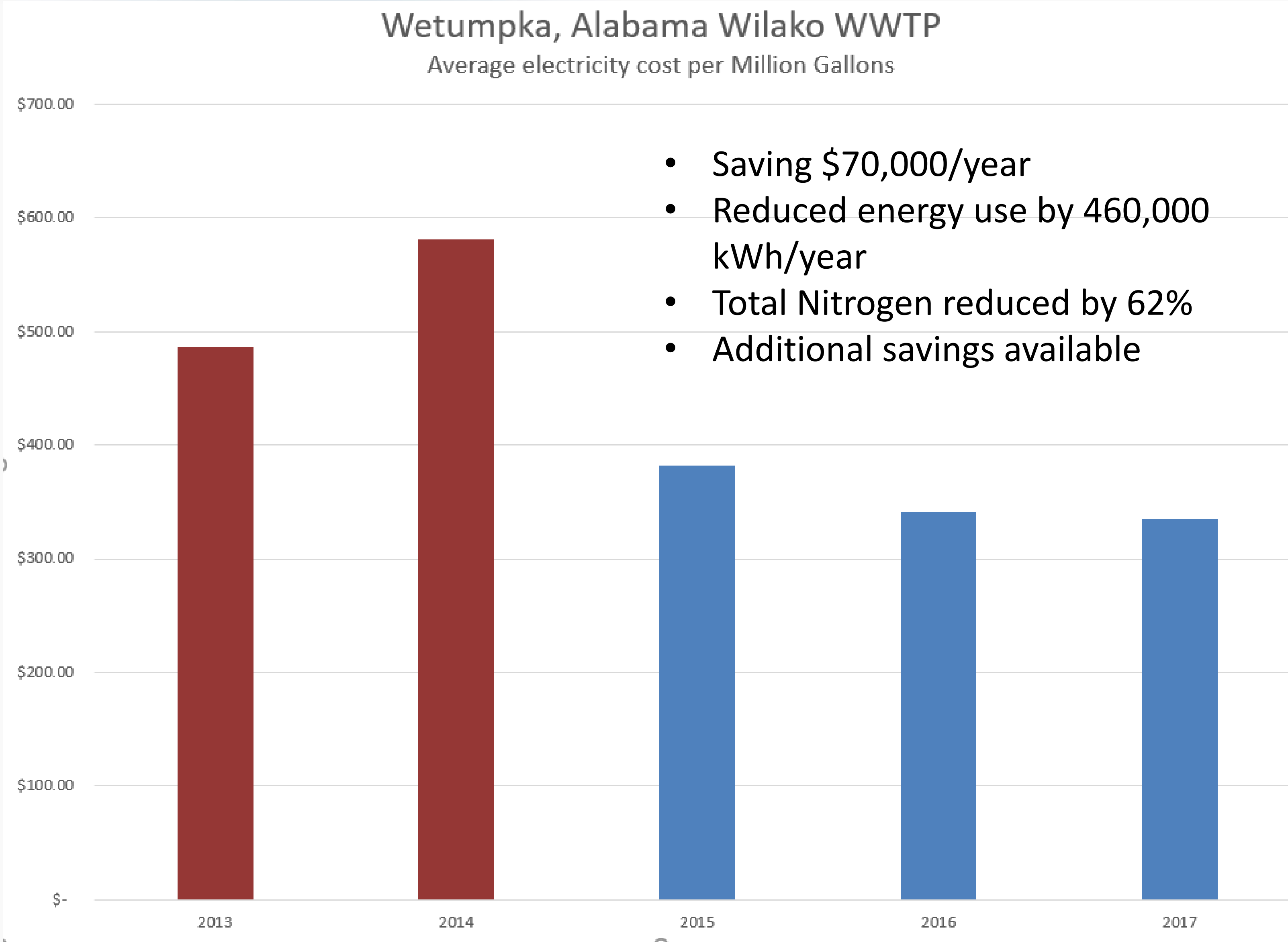
	Scenario 1	Scenario 2	Scenario 3
kW billing capacity	150	120	90
kWh consumed	45300	45300	45300
kWh/kW	302	378	503
Total kW cost	$711	$569	$426
kWh cost (up to 250 kWh/kW)	$3350	$2680	$2010
kWh cost (over 250 kWh/kW)	$2613	$2090	$1567
Base charge	$50	$50	$50
Total Charge	**$6723**	**$5389**	**$4054**
% Savings	-	*19.9%*	*39.7%*

Case Studies

- Each basin had six 75-HP aerators and 2 40-HP mixers running 24/y
- Took one basin and clarifier out of service
- Reduced runtimes of remaining aerators to 18 hrs/d.
- Reduced demand by 147 kW
- Improved energy efficiency by 24%

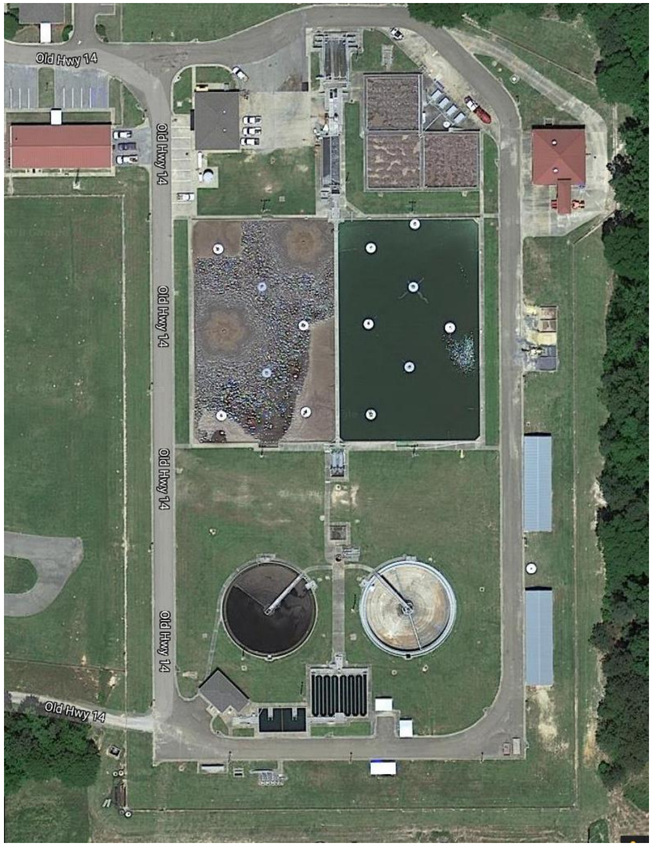
Wetumpka, AL

Wetumpka, AL


Wetumpka, Alabama Wilako WWTP
Average electricity cost per Million Gallons
$700.00
$600.00
$500.00
$400.00
$300.00
$200.00
$100.00
$-
2013
2014
2015
2016
2017
• Saving $70,000/year
• Reduced energy use by 460,000 kWh/year
• Total Nitrogen reduced by 62%
• Additional savings available

Then

Now



Wetumpka, AL

What is a kWh?

1000 kWh =

3000 miles in a Tesla Model S

What is a kWh?

1000 kWh =

1,590 Big Mac Burgers

What is a kWh?

1000 kWh =

What this guy eats each year
(…by April 1st)

Alexander City, AL

- Designed to treat domestic and industrial wastewater from a major textile manufacturer that closed during the recession.
- Eight 50-HP aerators running 24/7

Recommendations

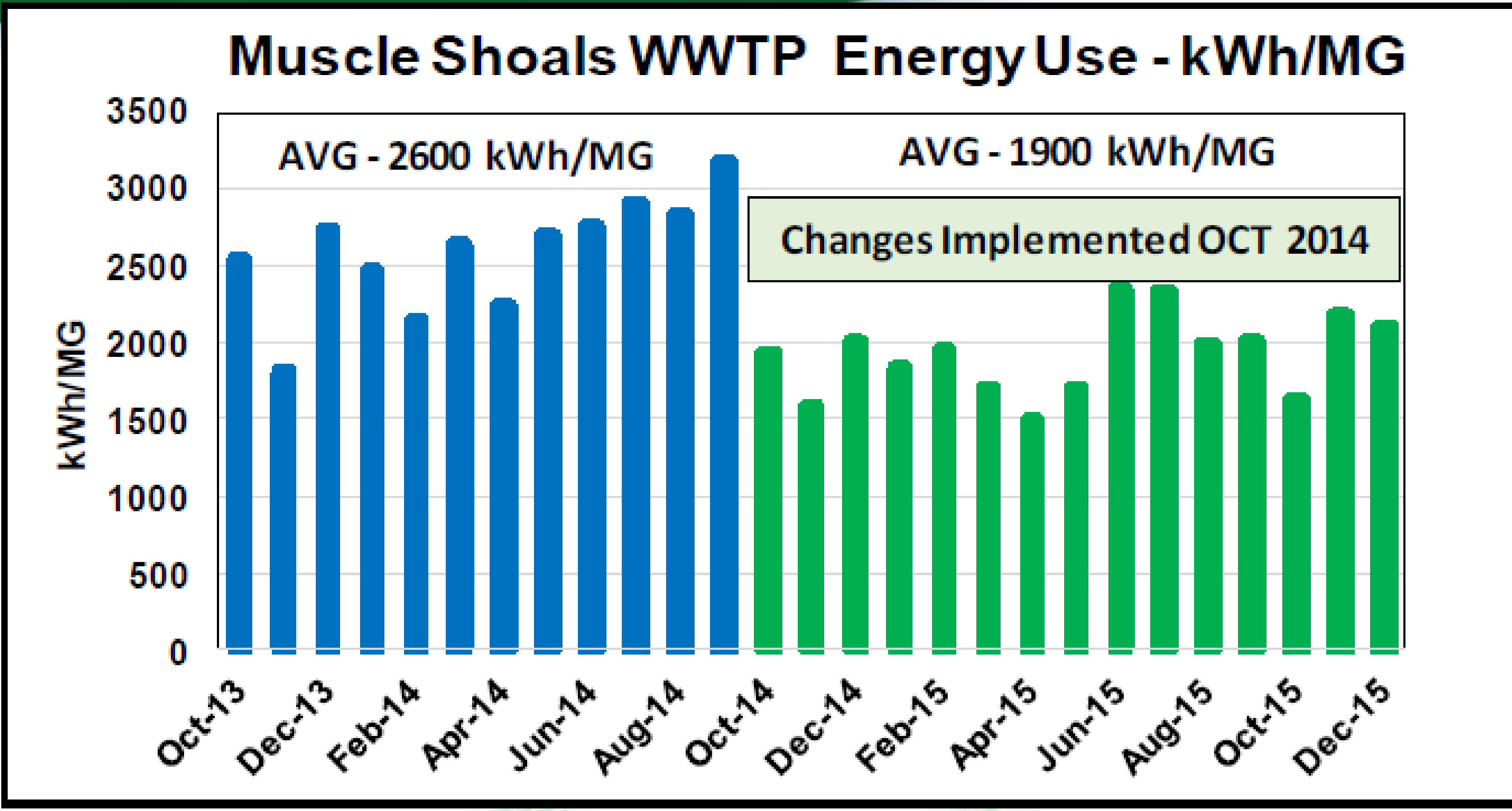
- Run 4 aerators at a time, alternating every 2 hours to maintain mixing
- Plant had to install motor control relays
- Reduced total energy use by over 1,200,000 kWh/year;
- Saving over $90k/year

Muscle Shoals, AL

- Pop. 13,000
- 4.0 MGD design capacity
- Treats 1.3 MGD
- BOD limit = 20 mg/L
- Ammonia limit 8 mg/L
- Discharges to Pond Creek, tributary to Tennessee River

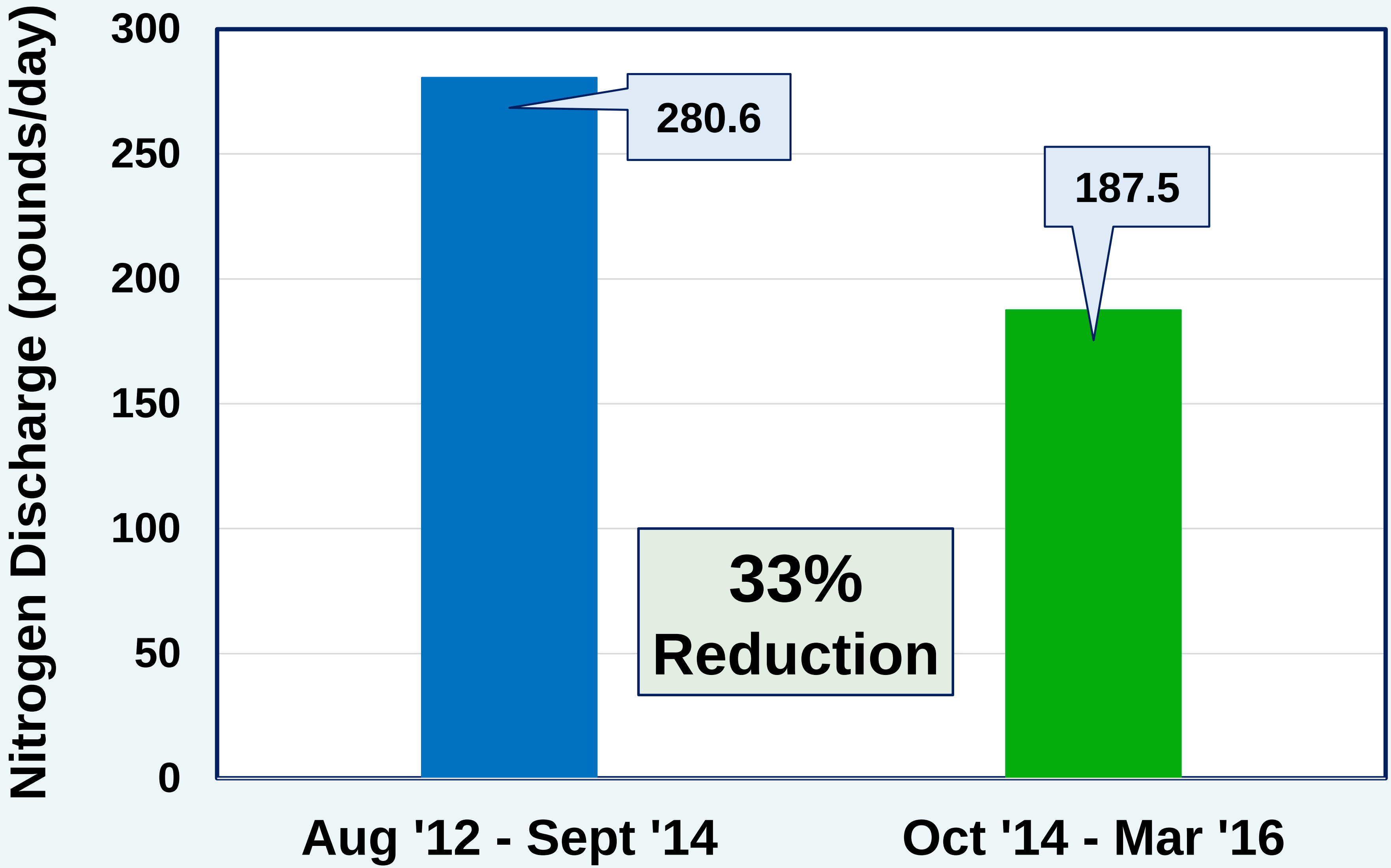
Recommendations

- Use a smaller 150 HP aerator year-round instead of seasonally using a 250 HP aerator
- Modify bacteria concentration
- Operate one basin only
- Use on-off aeration



- 27% reduction in energy use
- 350,000 kWh/year savings
- $11,000/year savings

Muscle Shoals, AL WWTP Nutrient Reduction



Resources

Bio-Tiger for Activated Sludge

THE UNIVERSITY OF MEMPHIS
Department of Civil Engineering

Bio-Tiger Model

Input

Activated Sludge Input Data	Current Conditions	Alternate Scenario
Temperature (°C)	20	20
S_o (mg/L)	200	200
V (mil gal)	1	1
Q (mgd)	1	1
Inert VSS (mg/L)	40	40
Oxidizable N (mg/L)	35	35
biomass (VSS/TSS)	0.85	0.85
Influent TSS (mg/L)	200	200
Inert Inorg TSS (mg/L)	20	20
Effluent TSS (mg/L)	8	8
RAS TSS (mg/L)	10000	10000
MLSS (mg/L)	3000	3000
f_d	0.1	0.1
Y	0.6	0.6
K_s (mg/L)	60	60
k_d at 20°C (1/day)	0.1	0.1
k at 20°C (1/day)	8	8

Aerator Performance Data	Current Conditions	Alternate Scenario
Operating DO concentration (mg/L)	4.5	2
alpha	0.84	0.84
beta	0.92	0.92
SOTR, lb O2 / hp-hr	2.7	2.7
Temperature (°C)	20	20
Aeration (hp) being operated	150	100
Elevation (ft)	200	200
Aerators operating time (hr/day)	24	24
Type of aerators (1, 2, or 3)	1	1
Speed of aerators (%)	100	85
Energy cost unit ($/kWh)	0.09	0.09

SRT (day)
1
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
48
50
52
54
56
58
60
62
64
66
68
70

Analysis

Revert to default

Output

Approximate Operating Conditions	Current Conditions	Alternate Scenario
Total average daily flow rate (mgd)	1.00	1.00
Aeration volume in service (mil gal)	1.00	1.00
Influent BOD5 concentration (mg/L)	200	200
Influent BOD5 mass loading (lb/day)	1,668	1,668
Sec ww Oxid N load (lb/day)	292	292
Sec ww TSS load (lb/day)	1,668	1,668
F/M ratio	0.089	0.089
Solids Retention Time (day)	28.0	28.0
MLSS (mg/L)	3,000	3,000
MLVSS (mg/L)	2,242	2,242
TSS Sludge Production (lb/day)	827	827
TSS in activated sludge effluent (lb/day)	66.7	66.7
Total Oxygen Requirements (lb/day)	3,121	3,121
Total Oxygen Req'd W/Denit. (lb/day)	2,687	2,687
Total oxygen supplied (lb/day)	3,394	3,185
Mixing intensity in the reactor (hp/mil gal)	150	85
RAS flow rate (mgd)	0.43	0.43
RAS recycle percentage (%)	42.9	42.9
WAS flow rate (mgd)	0.010	0.010
RAS TSS concentration (mg/L)	10,000	10,000
Total sludge production (lb/day)	894	894
Reactor Detention Time (hr)	24.0	24.0
VOLR (lb BOD/(thou cu ft-day))	12.48	12.48
Effluent CBOD5 (mg/L)	4.0	4.0
Effluent TSS (mg/L)	8.0	8.0
Effluent Ammonia-N (mg/L)	0.38	0.38
Effluent NO3-N (mg/L)	26.0	26.0
Effluent NO3-N W/denit (mg/L)	7.8	7.8

Actual Aerator Performance	Current Conditions	Alternate Scenario
Field OTR (lb O2 / hp-hr)	0.94	1.56
Aerator energy use (kWh/month)	70,200	39,780
Energy cost ($/month)	6,318	3,580
Cost savings vs. current conditions ($/month		2,738

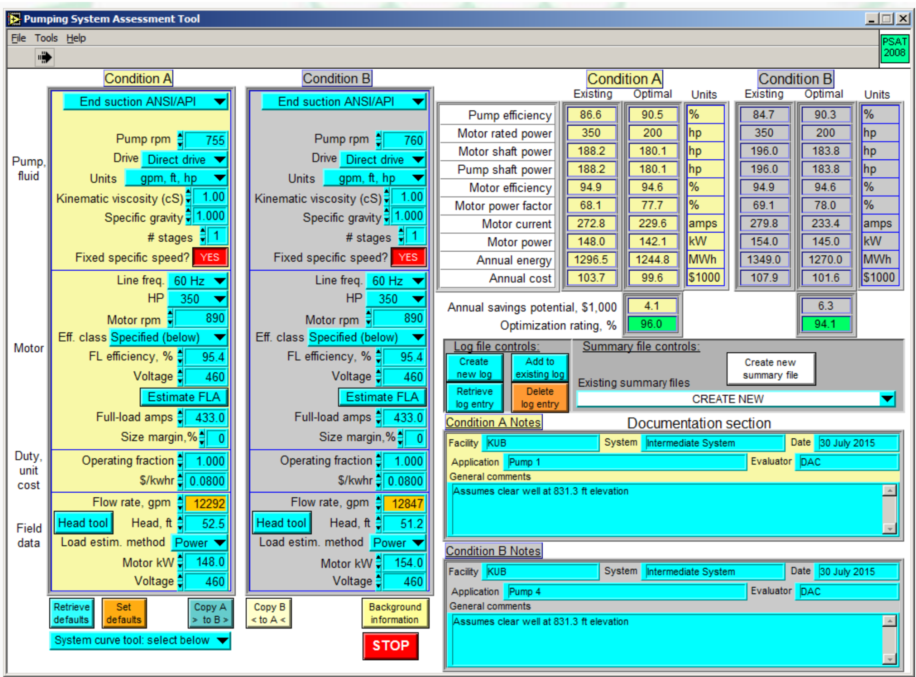
- Calculates oxygen demand based on process data
- User can develop equipment scenarios to match supply to demand
- Tool will estimate projected energy and cost savings, as well as nitrogen removal
- Freely available. Contact held.brendan@epa.gov for a copy and a tutorial.

Pump System Assessment Tool

<u>What is it?</u>

- Free tool downloadable from Department of Energy
- Uses flow rate, pressure, electrical measurements

- Snapshot of pump efficiency
- Compares efficiency to available pump/motor systems
- Estimates savings based on that comparison



Pump System Assessment Tool

Who does it?

- TVA customers can get a PSAT analysis through Comprehensive Services – contact local power company to request
- DOE has Industrial Assessment Centers
  - Must have annual energy bill >$100,000
  - Must be ~150 miles from Lexington
- DOE-certified PSAT qualified specialists (Google-able)

Incentive Programs

TVA Customers:

- Comprehensive services – evaluate pump & blower efficiency, PSAT analysis
- Energy Right Solutions – pays lesser of 70% of project cost or $0.10/kWh saved during first year
    - Need to apply in advance of project work
    - Incentive money can run out over course of FY
- EnerNOC Demand response – pays you to shut down during peak periods. No penalties.

Others:

- DSIRE – Database of Incentives for Renewables & Efficiency. Searchable by ZIP code.
- Call your local power company

Key Points

1. There’s money to be saved – and it doesn’t have to cost you much
2. Management has a BIG role
3. Start small – what do you pay for?
4. You’re not in it alone

Contact Information

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